Title: Analysis of Multispectral Imagery

Brief Overview:

Earth Resources Satellites, such as Landsat, record data in a multispectral format. Data is separated into several different bands each of which is highly sensitive to a particular portion of the visible and infrared spectrum. Vegetation patterns, land forms, and water resources can be studied and analyzed using these images. Combining image data with maps and other geographic or geologic resources yields a wealth of information about planet Earth. This Learning Unit focuses on the process of image analysis using Multispec Software.

Links to NCTM 2000 Standards:

- **Data Analysis**
  Students use the Multispec software to analyze spectral data values, and create graphs to display these values.

Links to National Science Education Standards:

- **Science as Inquiry**
  Students use computers and software to analyze and display Multispectral Image data.

- **Physical Science**
  Students apply their understanding of the Electromagnetic Spectrum, specifically the Visible and Infrared portions to analyze and interpret Earth Resources data.

- **Science in Personal and Social Perspective**
  Students learn how to interpret satellite data, and how it is used in analyzing natural resources and environmental factors.

Grade/Level:

Grades 9 - 12

Duration/Length

1 day

Prerequisite Knowledge:

Students should have a working knowledge of the following skills:

- Map reading

Student Outcomes/Objectives:

Students will:

- achieve an understanding of how to utilize satellite data in Earth Resources analysis.
- gain insight into how satellite data may be used to detect changes in the Earth System over time.
- understand the importance of spectral patterns in determining the physical characteristics of the land forms and vegetation imaged by satellites.

Materials/Resource/Printed Materials:

- Computers with Internet connection
- Multispec Software and User's Manual available free from Purdue University
  Download site: http://dynamo.ecn.purdue.edu/~biehl/MultiSpec/
- Landsat Image files available free from NASA
  Download site: http://observe.ivv.nasa.gov/nasa/education/tools/stepby/archive.html
- Maps of Washington D.C.
- General information about D.C. and surrounding areas. (This may be obtained through tourist information brochures which are normally free.)

Development/Procedure:

- Before beginning the lesson, do the following:

- Download the software, manual, and the Landsat image of Washington D.C. (available at the above websites).

- Install the software on a computer according to the instructions on the website. Both Multispec and the image files are self-extracting *.exe* files. It is recommended that the teacher reads the manual for Multispec and becomes familiar with the software.

- Begin lesson with explaining the Landsat spectral bands and the electromagnetic spectrum, with emphasis on the visible and infrared regions of the spectrum. See Attachment 1 for background information. Provide students with the list of Landsat spectral bands.

- Have the students open the image *DC.lan*. The default for this image is 3-channel color, with Channels 4, 3 and 2 in red, green, and blue respectively. View the image with the default settings first. Ask the students if they can guess or interpret what type of surfaces the different colors represent. See Attachment 2 for explanation.

- Give students the maps of Washington D.C. and, if they are not familiar with the region provide them with information materials of what can be found in D.C., i.e., The Mall, the White House, Lincoln Memorial, Airports, etc.

- Have the students locate items listed in Attachment 3, Student Worksheet 1. This exercise serves to familiarize students with looking at image data and detecting features.

- Instruct the students to separate the image into the different spectral bands by selecting *Process - Display Image - Type - Side by Side Channels*. This provides seven different gray scale images, one for each spectral band. Also, in the *Options Menu* select *New Selection Graph*. This will display a window showing a graph of reflectance values between 0 and 255 for a selected pixel or region for each band. A higher value indicates higher reflectance. Copies of the images are included.

- Use Attachment 4, Student Worksheet 2, and have students describe and explain why different features are more easily identified in certain bands. Example: Locate the Georgetown Reservoir, McMillan Reservoir, and the Tidal Basin (next to the Thomas Jefferson Memorial) on a map. Have the students look at these locations in the different spectral bands. The reservoirs and the basin become easily distinguishable in bands 4, 5, and 7, i.e., the infrared bands, because of their **low** reflectance in these bands compared to surrounding areas. This type of analysis would be used to distinguish between types of surfaces.

- Have students change the display settings in accordance with instructions on Attachment 5, Student Worksheet 3, and explain high/low reflectance values for different surface features in the respective channels. Students should use the list with Landsat spectral bands to aid them in this exercise.

- There are two options for displaying spectral values for a selection; using the *Selection Graph* or using the *List Data* command in the *Processor Menu*. Student Worksheet 3 explains how to use the *List Data* command. Once students have completed this Worksheet instruct them to look at the selection graph when they click in different areas of the image. They should detect that the scale is changing. Ask students to suggest a different graph type to display the spectral values for the features. Sample graphs are included in Attachment 6.

Assessment:

3 Student displays understanding of spectral patterns and their use in Earth Resources analysis by successfully and correctly completing the worksheets.

2 Student successfully completed Worksheets 1 and 2 and portions of Worksheet 3. Displays some understanding of spectral patterns.

1 Student successfully completed Worksheet 1, but had difficulty with Worksheet 2. Did not complete Worksheet 3.

0 Student was not able to complete any of the Worksheets.

Extension/Follow Up:

Have students select different images from the website. Students can work independently or in teams to perform an image analysis and then prepare a paper or a presentation describing their image and its features.

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Attachment 1

The Electromagnetic Spectrum

The Electromagnetic Spectrum is comprised of energy at different wavelengths, ranging from very long wavelengths, such as Radio- and Microwaves, to very short wavelengths, Gamma rays. Visible light and Infrared Radiation are the most important portions of the Electromagnetic spectrum when Landsat images are analyzed.

Visible light ranges in wavelengths from 700 nm (nano meters, 1 nm = 10^{-9} meters) to 400 nm, and is separated into seven different colors, red, orange, yellow, green, blue, indigo and violet.

Landsat Spectral Sensor

All different surface types on planet Earth reflect and absorb light in different ways. This spectral reflectance can be thought of as a fingerprint for a surface. The Landsat satellite measures this reflectance in seven different bands. Large areas of the planet can be analyzed for their vegetation and water content, mineral resources, urban expansion etc.

Band	Wavelength (micro-meters)	Description	Used for
1	.45 - .52	Blue Visible	Mapping water near coasts, mapping forest types, differentiating between soil and plants, identifying human made objects such as roads and buildings.
2	.52 - .60	Green Visible	Differentiating between types of plants, determining the health of plants, identifying human made objects.
3	.63 - .69	Red Visible	Differentiating between plant species, and identifying human made objects.
4	.76 - .90	Near Infrared energy	Determining plant types and health, and detecting boundaries of bodies of water.
5	1.55 - 1.75	Mid-infrared energy	Distinguishing snow from clouds, and determining soil moisture content.
6	10.4 - 12.5	Thermal-infrared	Determining relative temperature and amount of soil moisture.
7	2.08 - 2.35	Mid-infrared energy	Differentiating between mineral and rock types and detecting how much moisture plants are retaining.

When spectral bands are displayed separately in shades of gray, the lighter gray tones represent objects with higher reflectance in that band, the darker objects have lower reflectance.

Data from the Landsat satellites is available from year 1972 until present, making it feasible to detect changes in Earth's resources over time.

Attachment 2

The default setting for the DC image file is:

3-channel color

where the computer is instructed to display

Channel 4 Near Infrared energy as RED

Channel 3 Visible Red light as GREEN

Channel 2 Visible Green light as BLUE

Note that the computer display colors, RED, GREEN and BLUE are not the same as the Visible Light spectral bands. This is a FALSE color image.

Changing the channels as follows creates a TRUE color image:

Red Channel 3

Green Channel 2

Blue Channel 1

In this type of image the computer is instructed to display Visible Red light as RED, Visible Green light as GREEN, and Visible Blue light as BLUE.

In the FALSE color image RED is used for Near Infrared energy. Vegetation and land have very high reflectance in the Near Infrared band, while water absorbs almost all of the energy in this band. The RED areas on the image are different types of vegetation. Different shades of red indicate different types of land or vegetation.

The blue/green/gray color indicates human made structures, roads, bridges etc. These types of surfaces reflect RED, BLUE, and GREEN visible light, but have lower reflectance in the Near Infrared band.

The Potomac River and other water resources range from green to black in color, depending on the depth and clarity of the water. Deeper water is darker.

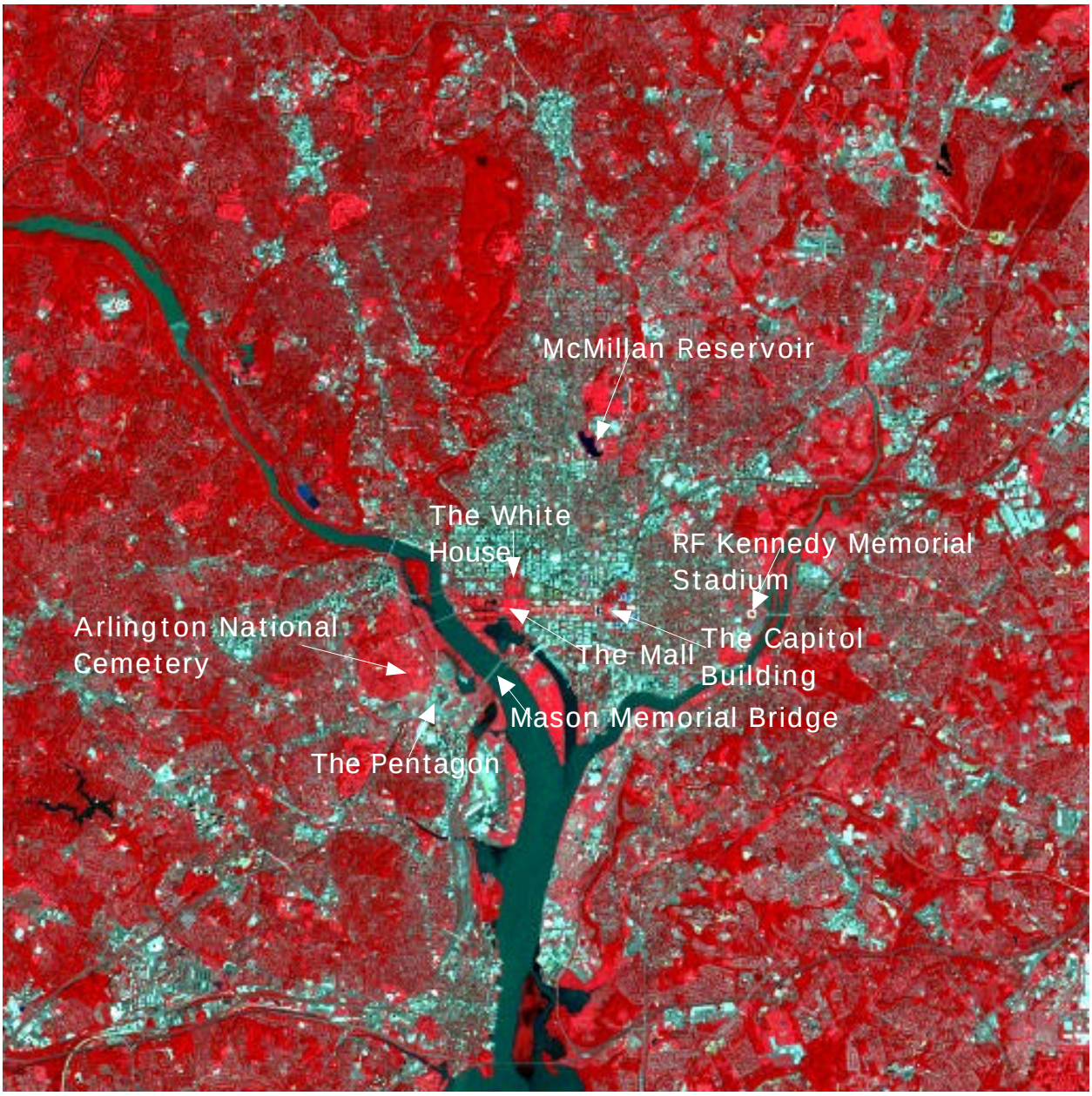
Attachment 3, Student Worksheet 1

In the *View* menu select *Coordinates Bar*
This will show display coordinates for a selection.

Locate the following features on the image of Washington D.C. and write down the approximate display coordinates:

Feature	Display Coordinate(s)
The Mall	_____
The Capitol Building	_____
Mason Memorial Bridge	_____
Arlington National Cemetery	_____
Washington National Airport	_____
The White House	_____
McMillan Reservoir	_____
The Pentagon	_____
RF Kennedy Memorial Stadium	_____

Attachment 3, Answer Key



Attachment 4, Student Worksheet 2

Locate the following features and explain in which spectral bands they are the most easily distinguishable and why.

Feature:	Easily Distinguishable in Band(s)	Reason
Georgetown Reservoir	_____	_____
Tidal Basin (near Lincoln Memorial)	_____	_____
Rock Creek Park	_____	_____
Runways at National Airport	_____	_____
The Capitol Building	_____	_____

Attachment 5, Student Worksheet 3, Example

Instructions:

Change the display settings to a single band according to list below. To change display settings do the following: Go to *Processor Menu* - select Display Image - select *Display Type:* in the drop down box select type - in the *Channels box* type in the channel number.

Have *Selection Graph* open. O*ptions Menu - New Selection Graph.*

Select *Coordinates bar* from the *View Menu*.

Click on the listed feature and then go to *Processor - List Data - Click OK*. This command will list spectral values for the selected coordinate and output to the Text Screen. Note that values will differ slightly depending on where in a particular area you click.

Display Type	Channel(s)	Type of reflectance	Feature	Reflectance values for each channel
Example:				
3-channel color	Red: 4	Near Infrared	McMillan	1: 63
	Green: 3	Visible Red	Reservoir	2: 23
	Blue: 2	Visible Green		3: 15
				4: 7
				5: 6
				6: 132
				7: 2

Explanation: McMillan reservoir is a water surface. Water reflects blue visible light, higher value in Channel 1, and absorbs Visible Red and Green, lower values in Channels 2 and 3. Almost no infrared energy is reflected, low values in Channels, 4, 5, 7. Channel 6 - Thermal Infrared measures relative temperature and soil moisture. To appreciate the thermal difference between surfaces it is best to use the 1-Channel Color setting and select Channel 6. This image shows that the Reservoir is cooler (dark in the image) than for example the center of the city (very bright).

Display Type	Channel(s)	Type of reflectance	Feature	Reflectance values for each channel
3-channel color	Red: 4	_____	Tidal Basin	1:_____
	Green: 3	_____		2:_____
	Blue: 2	_____		3:_____
				4:_____
				5:_____
				6:_____
				7:_____

Explanation:_____
_____
_____
_____

3-channel color	Red: 4	_____	Georgetown	1:_____
	Green: 3	_____	Reservoir	2:_____
	Blue: 2	_____		3:_____
				4:_____
				5:_____
				6:_____
				7:_____

Explanation:_____
_____
_____
_____

Both the Tidal Basin and the Georgetown Reservoir are water surfaces, yet it is evident that their reflectance patterns are different. Can you think of an explanation to this?

_____
_____
_____

Display Type	Channel(s)	Type of reflectance	Feature	Reflectance values for each channel
3-channel color	Red: 3	_____	Rock Creek Park	1:_____
	Green: 2	_____		2:_____
	Blue: 1	_____		3:_____
				4:_____
				5:_____
				6:_____
				7:_____

Explanation:_____
_____
_____
_____

What type of image is this? True or False color?_____

3-channel color	Red: 5	_____	East Potomac Park	1:_____
	Green: 4	_____		2:_____
	Blue: 2	_____		3:_____
				4:_____
				5:_____
				6:_____
				7:_____

This location is close to the Tidal Basin.
Explanation:_____
_____
_____
_____

Note. This band combination is good for separating trees and grassland. Comparing Rock Creek Park and the East Potomac Park which has the lightest green color?
_____

Knowing that East Potomac Park houses a golf course what type of vegetation do you think that this shade of green represents? Trees or grasslands? _____

Answer Key to Worksheet 2

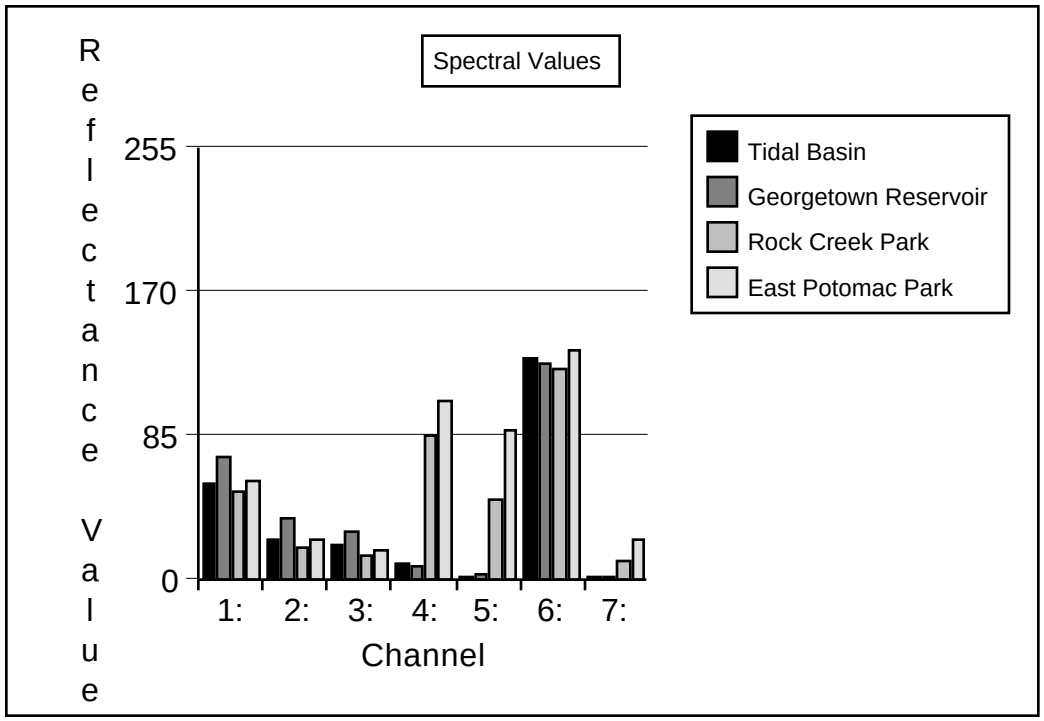
Feature:	Easily Distinguishable in Band(s)	Reason
Georgetown Reservoir	4, 5, 7	Water. Low reflectance in the infrared region. Makes it stand out.
Tidal Basin (near Lincoln Memorial)	4, 5, 7	Water. Low reflectance in the infrared region. Makes it stand out.
Rock Creek Park	All bands. Least visible in band 5.	Vegetation. Displays enough difference to surrounding areas in almost all bands to make it easy to see.
Runways at National Airport	4, 5	Darker than surrounding areas in these bands. Band 6 shows that the Airport region is hotter than surrounding areas.
The Capitol Building	1, 2, 3	High reflectance in the visible bands, compared to the surrounding lawn.

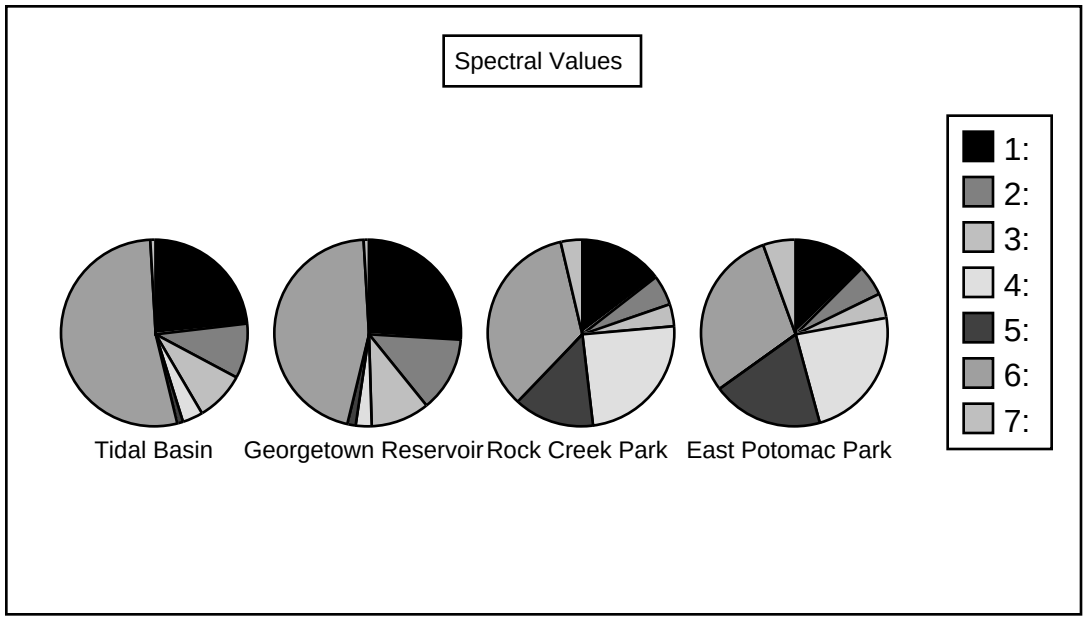
Answer Key to Worksheet 3

Channel	Tidal Basin	Georgetown Reservoir	Rock Creek Park	East Potomac Park
1:	57	73	52	59
2:	23	36	19	24
3:	21	28	14	18
4:	9	8	85	106
5:	2	3	48	88
6:	130	128	124	135
7:	1	1	11	23

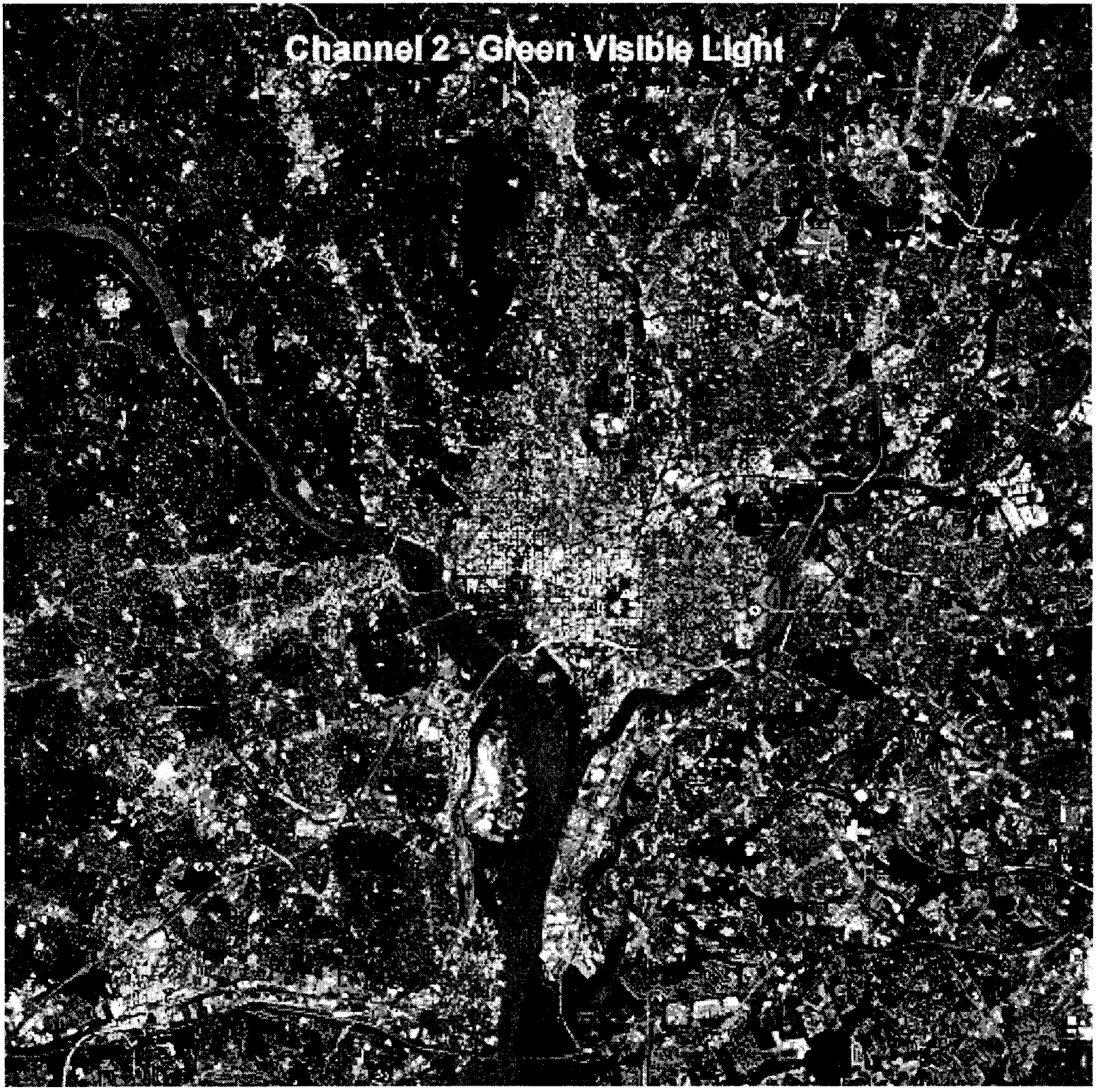
Please note that these values are approximate and depending on exactly where on the image the students place their cursors. You can elect to give them exact coordinates by having students type in exact coordinate values in the *List Data* command.

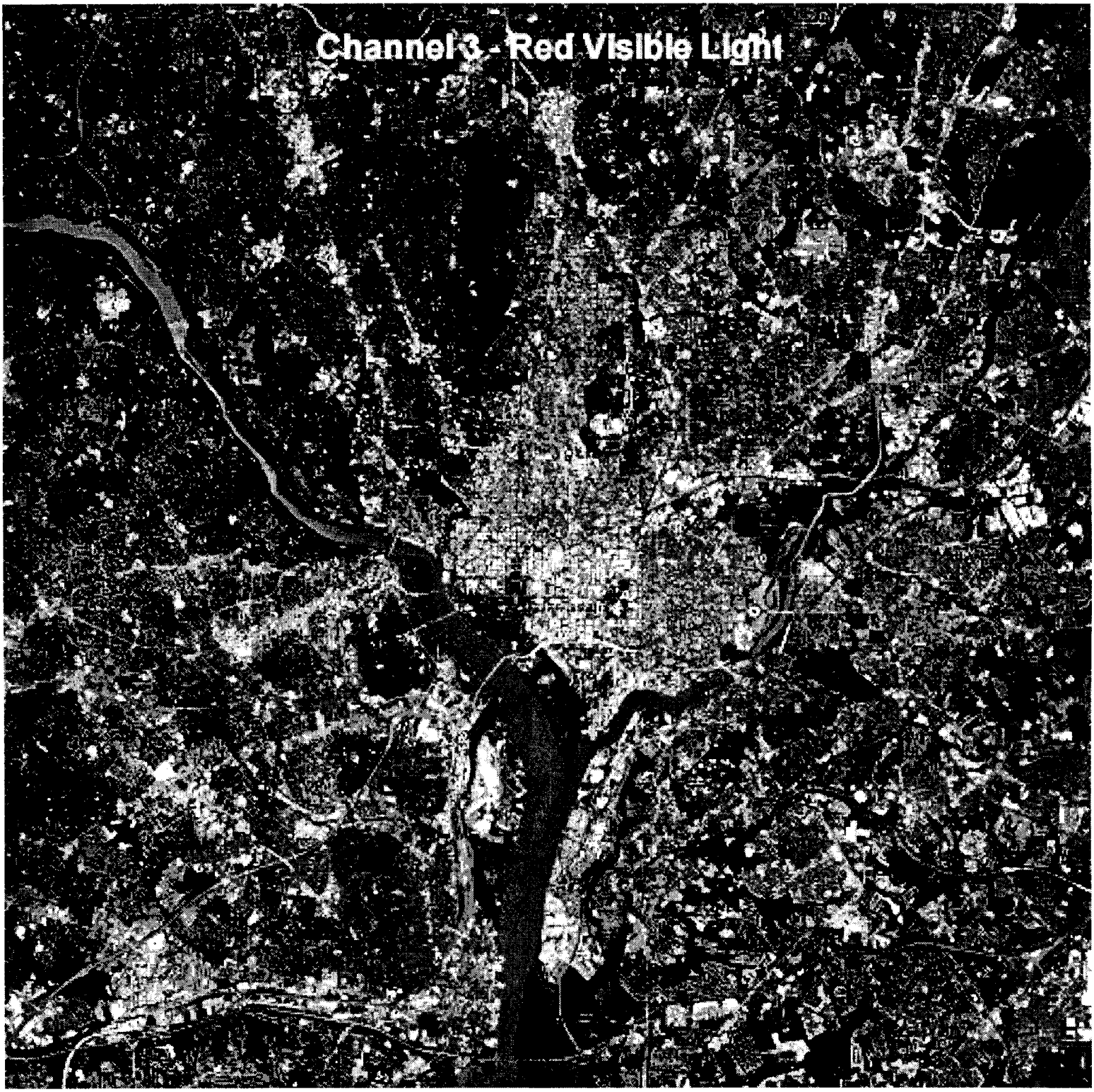
Attachment 6, Sample Graphs

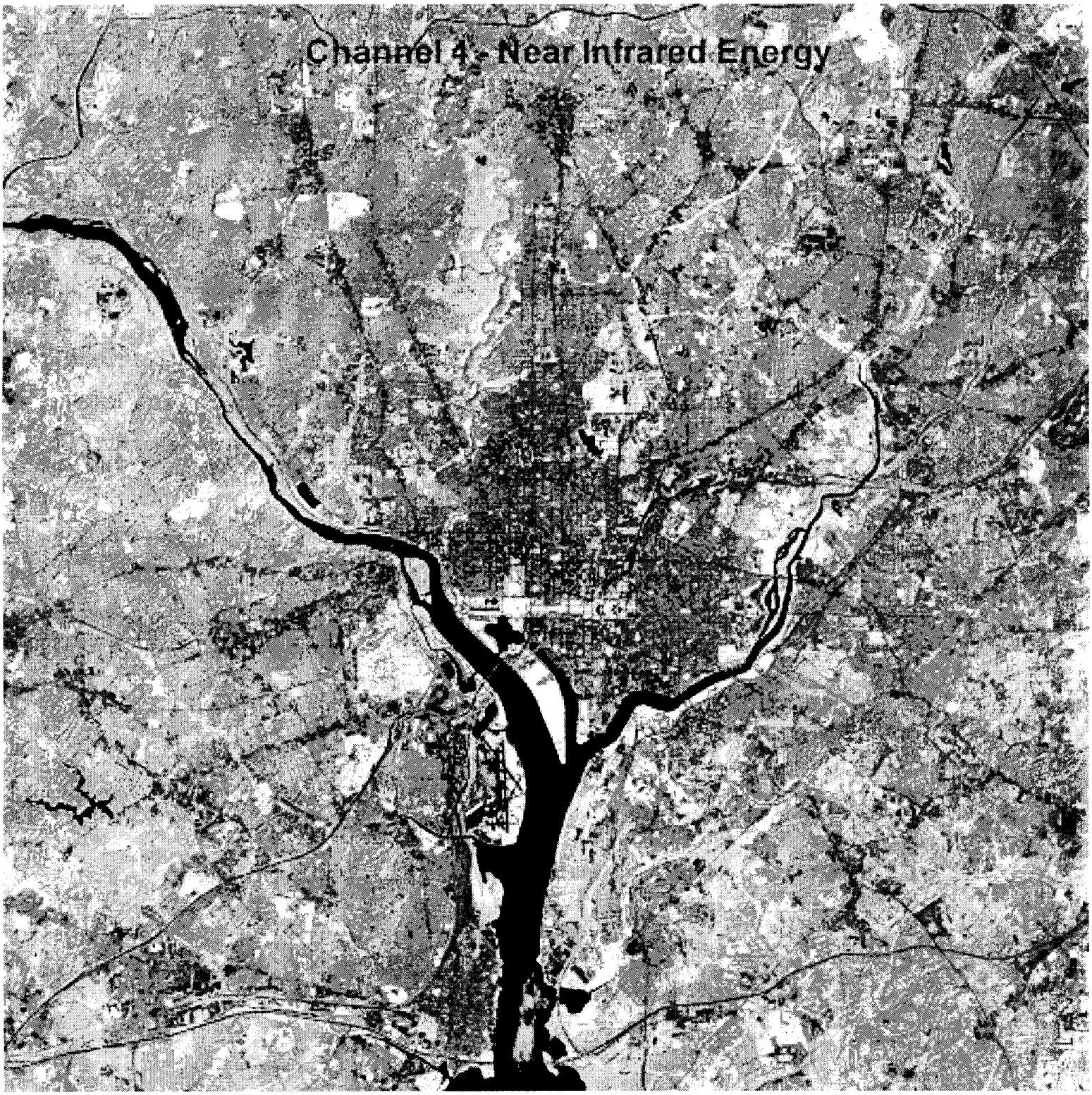




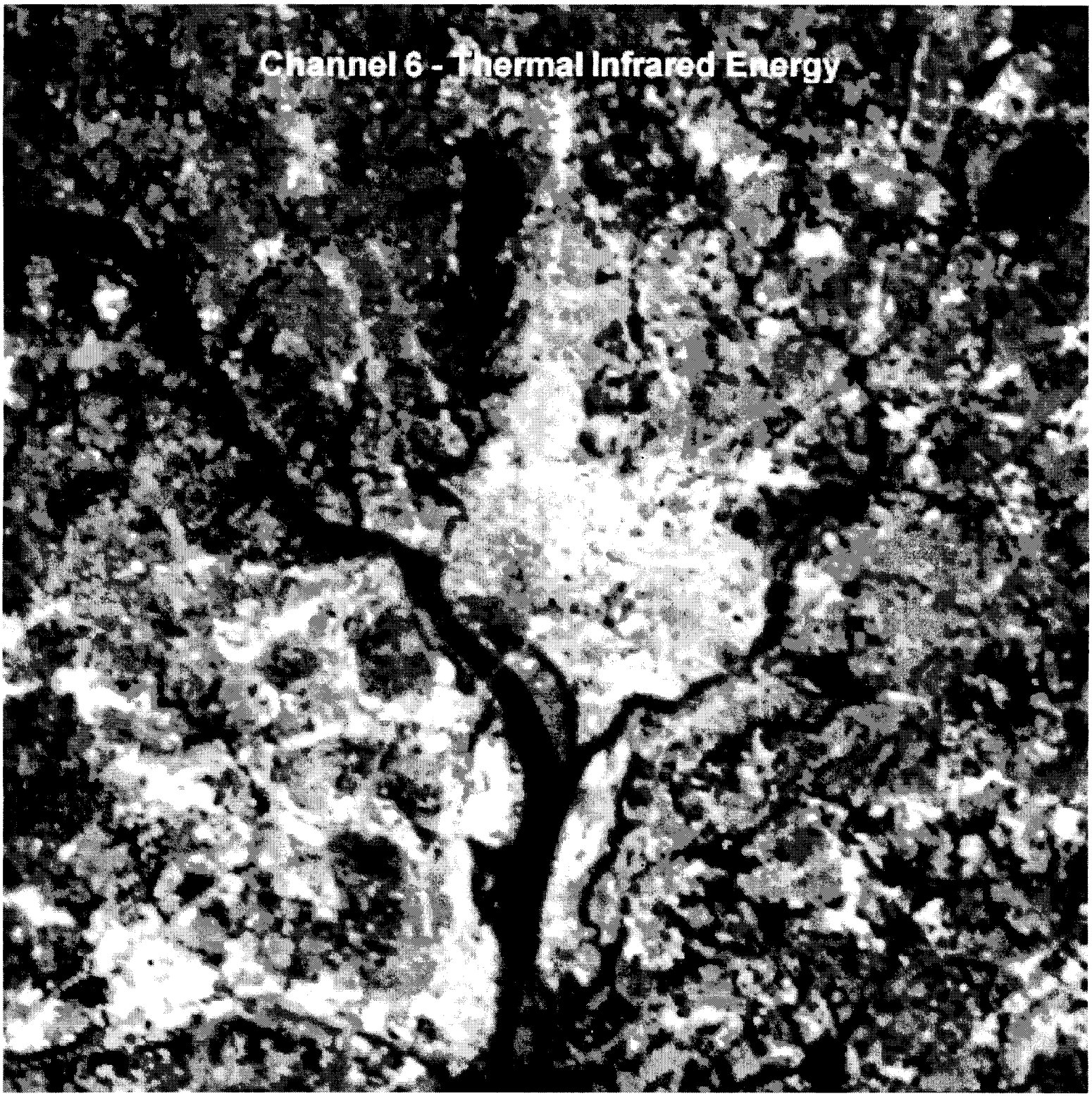

Channel 1 - Blue Visible Light

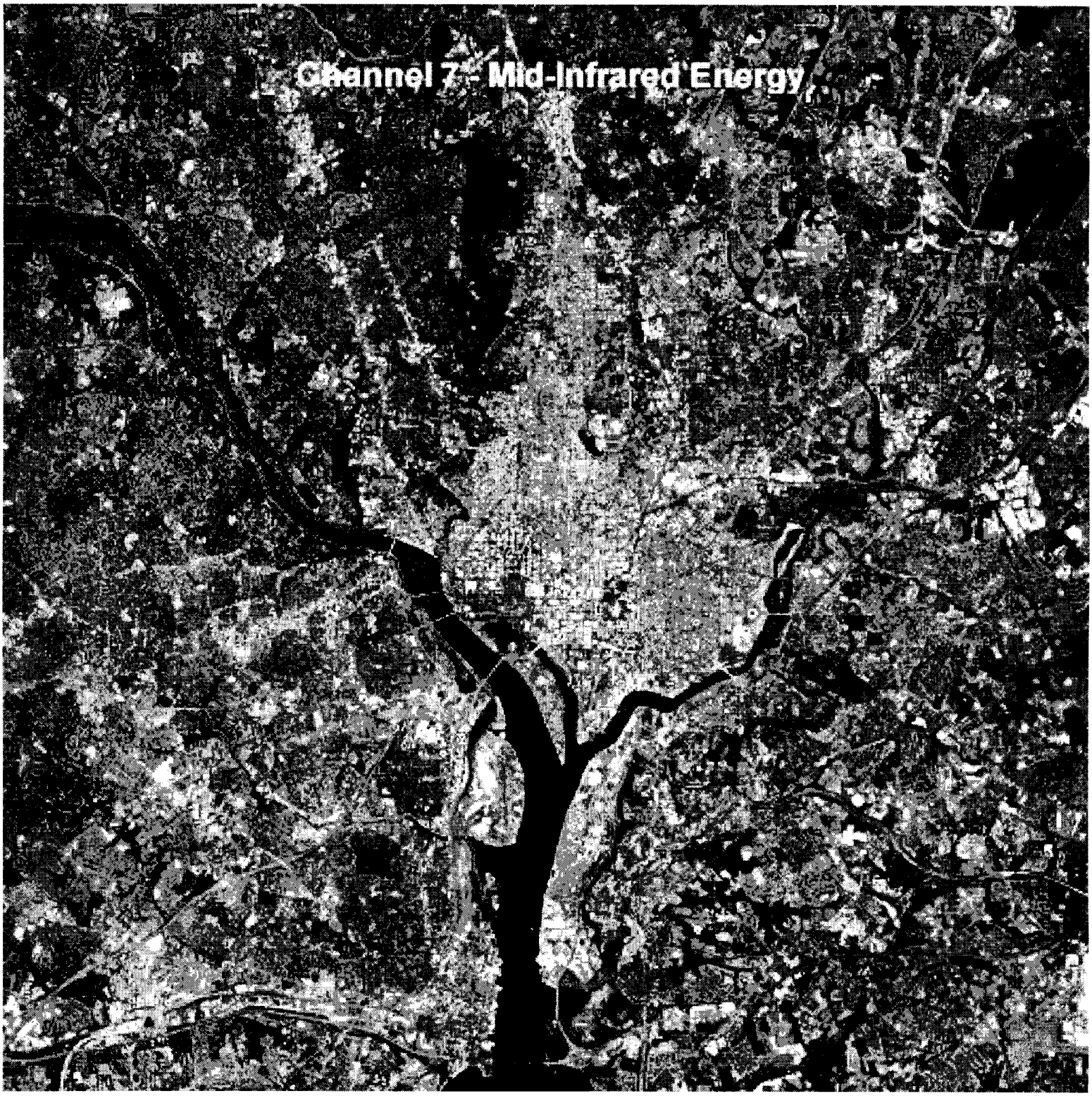

Channel 2 - Green Visible Light


Channel 3 - Red Visible Light


Channel 4 - Near Infrared Energy


Channel 5 - Mid-Infrared Energy


Channel 6 - Thermal Infrared Energy


Channel 7 - Mid-Infrared Energy